

AD-A081 041

CARNEGIE-MELLON UNIV PITTSBURGH PA DEPT OF PSYCHOLOGY
INDIVIDUAL DIFFERENCES IN MEMORY SPAN.(U)
JUL 79 W G CHASE, D R LYON, K A ERICSSON

F/G 5/10

N00014-79-C-0215

UNCLASSIFIED

NL

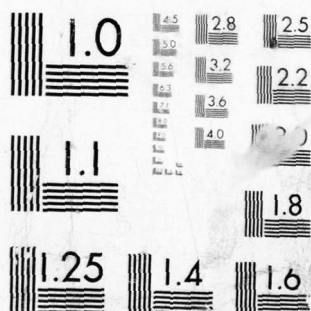
|OF|
AD-
A081041



END
DATE
FILMED

3-80

DDC



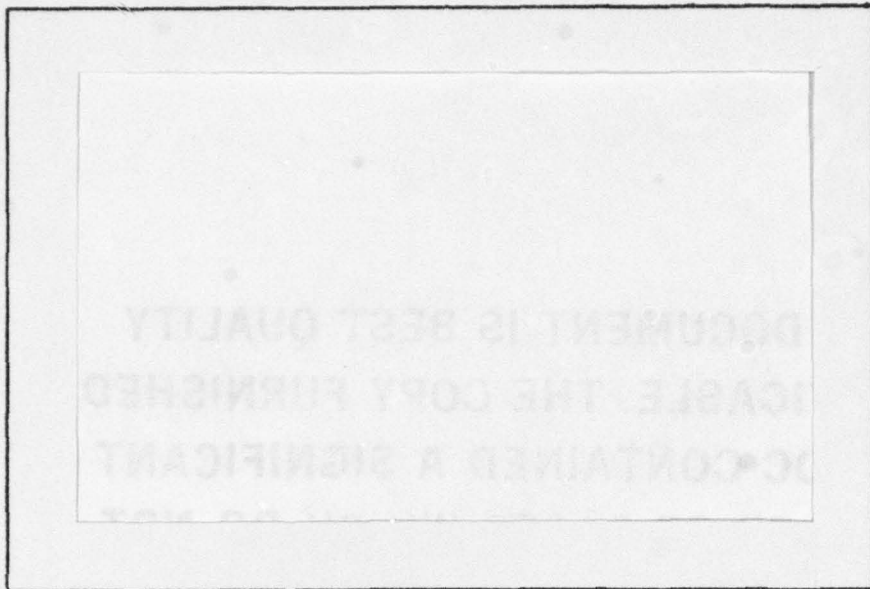
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ADA 081 041

DDC FILE COPY

LEVEL #

12
mw



DEPARTMENT
of
PSYCHOLOGY

DTIC
ELECTE
S FEB 25 1980 D
A



DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

Carnegie-Mellon University

80 2 21 023

DISCLAIMER NOTICE

**THIS DOCUMENT IS BEST QUALITY
PRACTICABLE. THE COPY FURNISHED
TO DDC CONTAINED A SIGNIFICANT
NUMBER OF PAGES WHICH DO NOT
REPRODUCE LEGIBLY.**

Individual Differences in Memory Span

William G. Chase

Carnegie-Mellon University

Don R. Lyon

University of Dayton and

K. Anders Ericsson

Carnegie-Mellon University

DTIC
ELECTE
S FEB 25 1980 D
A

Paper presented at the NATO International Conference on Intelligence and Learning, York, England, July 1979. To appear in M. Friedman, J.P. Das, & N. O'Connor (Eds.), Intelligence of Learning, New York: Plenum.

This research was sponsored by the Personnel and Training Research Programs, Psychological Science Division, Office of Naval Research, under Contract No. N00014-79-C-0215, Contract Authority Identification No., NR 157-430.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

Approved for public release; distribution unlimited.

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) <u>INDIVIDUAL DIFFERENCES IN MEMORY SPAN</u>		5. TYPE OF REPORT & PERIOD COVERED <u>9 Technical Repts</u>
6. PERFORMING ORG. REPORT NUMBER		7. AUTHOR(s) <u>William G. Chase</u> <u>Don R. Lyon</u> <u>K. Anders Ericsson</u>
8. CONTRACT OR GRANT NUMBER(s) <u>NR 157-430</u> <u>N00014-79-C-0215</u>		9. PERFORMING ORGANIZATION NAME AND ADDRESS <u>Department of Psychology</u> <u>Carnegie-Mellon University</u> <u>Pittsburgh, PA 15213</u>
10. CONTROLLING OFFICE NAME AND ADDRESS <u>Personnel and Training Research Programs</u> <u>Office of Naval Research</u> <u>Arlington, VA 22217</u>		11. REPORT DATE <u>July 1979</u>
12. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) <u>12 272</u>		13. NUMBER OF PAGES <u>9</u>
14. DISTRIBUTION STATEMENT (of this Report) <u>Approved for public release; distribution unlimited.</u>		15. SECURITY CLASS. (of this report)
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
18. SUPPLEMENTARY NOTES <u>Presented at the NATO International Conference on Intelligence and Learning, York, England, July, 1979. To appear in M. Friedman, J.P. Das, & N. O'Connor (Eds.), <u>Intelligence and Learning</u>. New York: Plenum.</u>		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) <u>Individual differences</u> <u>Memory Span</u> <u>Short-term memory</u> <u>Memory search</u> <u>Rehearsal</u> <u>Mnemonics</u>		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <u>One series of experiments examined the correlation between memory span and the speed of symbol manipulation in short-term memory, and another experiment analyzed the effects of extended practice on memory span. In the first study, most of the estimates of processing speed did not correlate with memory span, and it was concluded that short-term memory capacity is not determined by the speed of symbol manipulation in short-term memory. In the second study, memory span greatly increased with extended practice,</u>		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

387 876

elt

unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. but this increase was due to the acquisition of a mnemonic system.
Short-term memory capacity was unaffected by practice.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DDC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/ _____	
Availability Codes	
Dist.	Avail and/or special
A	23 C.F.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Abstract

One series of experiments examined the correlation between memory span and the speed of symbol manipulation in short-term memory, and another experiment analyzed the effects of extended practice on memory span. In the first study, most of the estimates of processing speed did not correlate with memory span, and it was concluded that short-term memory capacity is not determined by the speed of symbol manipulation in short-term memory. In the second study, memory span greatly increased with extended practice, but this increase was due to the acquisition of a mnemonic system. Short-term memory capacity was unaffected by practice.

Individual differences in memory span are interesting from both a psychometric and an information-processing point of view. From a psychometric perspective, memory span is an important item on IQ tests because of the high correlations between memory span and IQ scores. It has been suggested that memory span is a good index of mental retardation and brain damage, but in the normal adult population, it probably is not a very good predictor of high-school or college grades (Matarazzo, 1972). Some people have even gone so far as to suggest that a pure measure of memory span--span ability--is the best culture-free determiner of intelligence (Bachelder & Denny, 1977a,b).

From an information-processing point of view, memory span is the most often used measure of short-term memory capacity, which in turn is one of the most important human limitations in thinking and problem solving (Newell & Simon, 1972). Recent information-processing studies by Cohen and Sandberg (1977) and Lyon (1977) have ruled out any obvious mnemonic coding strategies as causes of individual differences in short-term memory capacity.

It has been suggested by several people in the information-processing literature that memory span is related to the speed of mental processes in short-term memory. For example, Hunt, Frost and Lunneborg (1973), in their attempt to link psychometric and information-processing theories of intelligence, suggested that verbal intelligence is related to the speed of short-term memory processes. Baddeley, Thompson and Buchanan (1975) suggested that the speed of the rehearsal loop determines the memory span, in large part, because verbal items--those based on a phonemic code--tend to decay away within about 2 sec, and the function of rehearsal is to keep them from decaying. From their analysis of reading rates and memory spans, Baddeley et al concluded that people's memory spans are roughly equivalent to the number of words they can read in 2 sec. In a similar analysis, Cavanagh (1972) has suggested that there is a direct relationship between memory span and short-term memory search rates. From his analysis of memory span and scanning rates, Cavanagh concluded that it takes about 1/4 sec to search short-term memory. The implication is that people's memory search rates are determined by how many items are searched in 1/4 sec.

In this paper we will summarize work in our laboratory on two questions. First, are individual differences in memory span due to differences in the speed of symbol manipulation in short-term memory? And second, is it possible to increase one's short-term memory capacity with extended practice?

Speed of Symbol Manipulation

To summarize in advance our analysis of the first question, we have found very little evidence to support the idea that memory span is determined by the speed of symbol manipulation in short-term memory, at least in the college student population. We have run a series of experiments designed to establish the correlation between short-term memory processing rates and memory span, and one of the most interesting things we found was that the correlation between memory span and rehearsal rate is an artifact. In two studies, no relation was found between people's memory spans and their rehearsal rates for lists of digits well below memory span (3, 4, and 5 digits), but for lists that approach the memory span (6 digits), the correlation is about .50. This correlation is an artifact because people with low memory spans experience difficulties in remembering as memory load increases, and as a result, their rehearsal rate is slowed. There is no relationship between rehearsal rate and memory span for lists of digits below memory span.

In a larger study of 31 college students, we obtained, in addition to memory spans, reliable estimates of several information processing rates. These estimates included search for the presence of an item in short-term memory (Sternberg, 1966), search for the location of an item in short-term memory (Sternberg, 1967), and metered memory search (Weber & Castleman, 1969) in both short-term and long-term memory. The long-term metered memory search task in this study was alphabet search. In this task, the subject is presented both with a probe and a meter, and he must find the item located n places from the probe, where n is the meter. For example, a letter (H) and a number (3) are presented and the task is to name, as quickly as possible, the letter that appears 3 places later in the alphabet (K). This same procedure was used for short-term metered memory search except that the material to be searched is a random list of digits in short-term memory. In addition to these memory

search tasks, we measured the corresponding visual search speeds because we wanted an estimate of processing rates uncontaminated by memory load. Finally, we estimated several components of the rehearsal process, including the time to start rehearsal and the time to execute rehearsal. Start time is the time between onset of a GO signal and rehearsal of the first item, and execution time is the average inter-item time during rehearsal. The correlations between these various processing rates and memory span are shown in Table 1, along with the reliabilities. (Digit span reliability was .96.)

 Insert Table 1 about here

None of the visual search speeds correlated with memory span, nor did memory search for presence. The correlation between memory span and rehearsal execution time increased with memory load as before, but even with large memory loads the correlation was only -.41. Finally, the correlation between memory search for location and memory span is due to the same artifact that underlies the correlation between memory span and rehearsal.

There were only three non-artifactual correlations with memory span: metered short-term memory search, metered alphabet search, and rehearsal start time. At this point we can only speculate about the source of these correlations. In the metered short-term memory search task, it is possible that concurrent indexing (counting items until the meter is reached) imposes an additional load on short-term memory. This concurrent memory load could cause people with low memory spans to slow down. The correlations in the other two tasks--alphabet search and rehearsal start time--may indicate that people with low memory spans are also slower at activating information in memory. That is, people with low memory spans seem to be slower at accessing information in long-term memory, in secondary memory, or in whatever inactive storage systems are used when information is not in short-term memory, but once information is activated, they seem to process it at the same rate as people with high memory spans.

The data in these studies provide very little support for the idea that memory span is determined by the speed of symbol manipulation in short-term memory. If anything, our data suggest that memory span may indirectly affect processing rates. That is, people with low

memory spans may experience delays in processing as the memory load increases because they are forced to take extra time to update their short-term memory.

If the speed of symbol manipulation in short-term memory is not the major cause of individual differences in memory span, then what is? A good case can be made that memory span depends upon long-term memory knowledge structures and processes built up with practice (Chi, 1976). In the next section we explore the issue of whether short-term memory capacity can be increased with practice. An illustrative case study shows that digit span can be increased seemingly indefinitely if long-term memory coding structures are built up with practice.

Extended Practice

There are reports in the literature of increases in memory span with substantial amounts of practice (Gates & Taylor, 1925; Martin & Fernberger, 1924). Since memory span is such an essential ingredient both in psychometric theories of intelligence and information processing theories of thinking, it is of some interest to understand the nature of these practice effects. In our laboratory, we practiced one individual for about an hour a day, 3-5 days a week, for a year on the memory span task. In that time, his memory span increased steadily from seven digits to over fifty digits. How did he do it, and did he increase his short-term memory capacity?

Our analysis (Chase & Ericsson, 1978) indicates that this subject developed an elaborate mnemonic system, based primarily on running times for various races (e.g., 339 = three minutes and thirty-nine seconds, near world-record mile time). Our analysis further indicated that there was no increase in short-term memory capacity. The evidence is the following. First, when the subject groups digits together to form mnemonic codes, his groups are almost always 3- and 4-digit groups, and he has never generated a group larger than five digits. Second, the subject always maintains the last few digits (4-6 digits) as an uncoded rehearsal group, and he never allows the rehearsal group to exceed six digits. In fact, a 6-digit rehearsal group invariably is segmented as two groups of three digits. Third, the subject also hierarchically groups his groups together into supergroups. After some

initial difficulty in remembering 5-group supergroups, the subject generally uses 3-group supergroups and he never allows a supergroup to exceed 4 groups. Finally, when the subject was switched from digits to letters of the alphabet, there was no transfer, and his memory span dropped back to about six consonants.

The outcome of this study makes it clear that one must distinguish between memory span and short-term memory capacity. Memory span is limited both by the capacity of short-term memory and by coding processes, and the more elaborate the coding processes, the greater will be the discrepancy between memory span and short-term memory capacity. It is certainly possible to increase memory span by learning to code information so that it can be retrieved from long-term memory, but it does not seem possible to increase the capacity of short-term memory. It remains an important question to determine the extent to which the correlation between memory span and IQ is due to short-term memory capacity per se, and the extent to which coding processes are important.

References

- Bachelder, B.L., & Denny, M.R. A theory of intelligence: I. Span and the complexity of stimulus control. Intelligence, 1977, 1, 127-150. (a)
- Bachelder, B.L., & Denny, M.R. A theory of intelligence: II. The role of span in a variety of intellectual tasks. Intelligence, 1977, 1, 237-256. (b)
- Baddeley, A.D., Thompson, N., & Buchanan, M. The word length effect and the structure of short-term memory. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 575-589.
- Cavanagh, J.P. Relation between the immediate memory span and the memory search rate. Psychological Review, 1972, 79, 525-530.
- Chase, W.G., & Ericsson, R.A. Acquisition of a mnemonic system for digit span. Paper presented at the nineteenth annual meeting of the Psychonomic Society, San Antonio, Texas, November 1978.
- Chi, M.T.H. Short-term memory limitations in children: Capacity or processing deficits? Memory & Cognition, 1976, 4, 559-572.
- Cohen, R.L., & Sandberg, T. Relation between intelligence and short-term memory. Cognitive Psychology, 1977, 9, 534-554.
- Gates, A.I., & Taylor, G.A. An experimental study of the nature of improvement resulting from practice in a mental function. Journal of Educational Psychology, 1925, 16, 583-592.
- Hunt, E.B., Frost, N., & Lunneborg, C.E. Individual differences in cognition: A new approach to intelligence. In G. Bower (Ed.), Advances in learning and motivation, Vol. 7, New York: Academic Press, 1973. Pp. 87-122.
- Lyon, D.R. Individual differences in immediate serial recall: A matter of mnemonics? Cognitive Psychology, 1977, 9, 403-411.
- Martin, P.R., & Fernberger, S.W. Improvement in memory span. American Journal of Psychology, 1929, 41, 91-94.
- Matarazzo, J. The measurement and appraisal of adult intelligence. Baltimore, MD: Williams & Wilkins, 1972.
- Newell, A., & Simon, H.A. Human problem solving. Englewood Cliffs, NJ: Prentice Hall, 1972.
- Sternberg, S. High speed scanning in human memory. Science, 1966, 153, 652-654.
- Sternberg, S. Retrieval of contextual information from memory. Psychonomic Science, 1967, 8, 55-56.
- Weber, R.J., & Castleman, J. Metered memory search. Psychonomic Science, 1969, 16, 311-312.

Footnote

Preparation of this article was supported by contract N00014-79-C-0215 from the Advanced Research Projects Agency. We are indebted to M.T.H. Chi for her helpful comments.

Requests for reprints should be sent to William G. Chase, Department of Psychology, Carnegie-Mellon University, Pittsburgh, PA 15213.

Table 1

Processing Speed Reliabilities (odd-even)
and Correlations with Digit Span

	Reliability Coefficient	Correlation With Digit Span
Visual Search for Presence	.90	.23
Visual Search for Location	.74	-.0-
Visual Metered Search	.84	-.17
Memory Search for Presence	.95	-.17
Memory Search for Location	.82	-.63**
Memory Metered Search	.87	-.62**
Alphabet Metered Search	.95	-.46**
Rehearsal Start Time	.99	-.59**
Rehearsal Execution Time	.99	-.38*

$p < .05^*$
 $p < .01^{**}$

Navy

- 1 Dr. Ed Aiken
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Dr. Robert Blanchard
Navy Personnel R&D Center
Managment Support Department
San Diego, CA 92151
- 1 Mr. James S. Duva
Chief, Human Factors Laboratory
Naval Training Equipment Center
(Code N-215)
Orlando, Florida 32813
- 1 DR. PAT FEDERICO
NAVY PERSONNEL R&D CENTER
SAN DIEGO, CA 92152
- 1 Dr. John Ford
Navy Personnel R&D Center
San Diego, CA 92152
- 1 LT Steven D. Harris, MSC, USN
Code 6021
Naval Air Development Center
Warminster, Pennsylvania 18974
- 1 CDR Wade Helm
PAC Missile Test Center
Point Mugu, CA 93041
- 1 CDR Robert S. Kennedy
Naval Aerospace Medical and
Research Lab
Box 29407
New Orleans, LA 70189
- 1 Dr. Norman J. Kerr
Chief of Naval Technical Training
Naval Air Station Memphis (75)
Millington, TN 38054
- 1 CHAIRMAN, LEADERSHIP & LAW DEPT.
DIV. OF PROFESSIONAL DEVELOPMENT
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

Navy

- 1 Dr. William L. Maloy
Principal Civilian Advisor for
Education and Training
Naval Training Command, Code 00A
Pensacola, FL 32508
- 1 Dr. Kneale Marshall
Scientific Advisor to DCNO(MPT)
OP01T
Washington DC 20370
- 1 CAPT Richard L. Martin
USS Francis Marion (LPA-249)
FPO New York, NY 09501
- 1 Dr. James McBride
Navy Personnel R&D Center
San Diego, CA 92152
- 2 Dr. James McGrath
Navy Personnel R&D Center
Code 306
San Diego, CA 92152
- 1 CDR. MERCER
CNET LIAISON OFFICER
AFHRL/FLYING TRAINING DIV.
WILLIAMS AFB, AZ 85224
- 1 Dr. George Moeller
Head, Human Factors Branch
Naval Submarine Medical Research Lab
Groton, CN 06340
- 1 Dr William Montague
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Commanding Officer
U.S. Naval Amphibious School
Coronado, CA 92155
- 1 Commanding Officer
Naval Health Research
Center
Attn: Library
San Diego, CA 92152

Navy

- 1 Naval Medical R&D Command
Code 44
National Naval Medical Center
Bethesda, MD 20014
- 1 Library
Navy Personnel R&D Center
San Diego, CA 92152
- 6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390
- 1 JOHN OLSEN
CHIEF OF NAVAL EDUCATION &
TRAINING SUPPORT
PENSACOLA, FL 32509
- 1 Psychologist
ONR Branch Office
495 Summer Street
Boston, MA 02210
- 1 Psychologist
ONR Branch Office
536 S. Clark Street
Chicago, IL 60605
- 1 Office of Naval Research
Code 200
Arlington, VA 22217
- 1 Office of Naval Research
Code 437
800 N. Quincy Street
Arlington, VA 22217
- 1 Office of Naval Research
Code 441
800 N. Quincy Street
Arlington, VA 22217
- 1 Director
Engineering Psychology Programs
Code 455
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

Navy

- 5 Personnel & Training Research Programs
(Code 458)
Office of Naval Research
Arlington, VA 22217
- 1 Psychologist
OFFICE OF NAVAL RESEARCH BRANCH
223 OLD MARYLEBONE ROAD
LONDON, NW, 15TH ENGLAND
- 1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101
- 1 Scientific Director
Office of Naval Research
Scientific Liaison Group/Tokyo
American Embassy
APO San Francisco, CA 96503
- 1 Office of the Chief of Naval Operations
Research, Development, and Studies Branch
(OP-102)
Washington, DC 20350
- 1 LT Frank C. Petho, MSC, USNR (Ph.D)
Code L51
Naval Aerospace Medical Research Laboratory
Pensacola, FL 32508
- 1 DR. RICHARD A. POLLAK
ACADEMIC COMPUTING CENTER
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402
- 1 Dr. Gary Poock
Operations Research Department
Naval Postgraduate School
Monterey, CA 93940
- 1 Roger W. Remington, Ph.D
Code L52
NAMRL
Pensacola, FL 32508
- 1 Dr. Bernard Rimland
Navy Personnel R&D Center
San Diego, CA 92152

Navy

- 1 Mr. Arnold Rubenstein
Naval Personnel Support Technology
Naval Material Command (08T244)
Room 1044, Crystal Plaza #5
2221 Jefferson Davis Highway
Arlington, VA 20360
- 1 Dr. Worth Scanland
Chief of Naval Education and Training
Code N-5
NAS, Pensacola, FL 32508
- 1 Dr. Sam Schifflett
Systems Engineering Test Directorate
U.S. Naval Air Test Center
Patuxent River, MD 20670
- 1 A. A. SJOHOLM
TECH. SUPPORT, CODE 201
NAVY PERSONNEL R & D CENTER
SAN DIEGO, CA 92152
- 1 Mr. Robert Smith
Office of Chief of Naval Operations
OP-987E
Washington, DC 20350
- 1 Dr. Alfred F. Smode
Training Analysis & Evaluation Group
(TAEG)
Dept. of the Navy
Orlando, FL 32813
- 1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152
- 1 CDR Charles J. Theisen, JR. MSC, USN
Head Human Factors Engineering Div.
Naval Air Development Center
Warminster, PA 18974
- 1 W. Gary Thomson
Naval Ocean Systems Center
Code 7132
San Diego, CA 92152

Army

- 1 HQ USAREUE & 7th Army
ODCSOPS
USAREUE Director of GED
APO New York 09403
 - 1 LCOL Gary Bloedorn
Training Effectiveness Analysis Division
US Army TRADOC Systems Analysis Activity
White Sands Missile Range, NM 88002
 - 1 DR. RALPH DUSEK
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
 - 1 Col Frank Hart
Army Research Institute for the
Behavioral & Social Sciences
5001 Eisenhower Blvd.
Alexandria, VA 22333
 - 1 Dr. Ed Johnson
Army Research Institute
5001 Eisenhower Blvd.
Alexandria, VA 22333
 - 1 Dr. Michael Kaplan
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
 - 1 Dr. Milton S. Katz
Individual Training & Skill
Evaluation Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333
 - 1 Dr. Beatrice J. Farr
Army Research Institute (PERI-OK)
5001 Eisenhower Avenue
Alexandria, VA 22333
 - 1 Technical Director
U.S. Army Human Engineering Labs
Aberdeen Proving Ground, MD 21005
- 16

Army

- 1 Dr. Harold F. O'Neil, Jr.
Attn: PERI-OK
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 LTCOL Michael T. Plummer
Organizational Effectiveness Division
Office of the Deputy Chief of Staff
for Personnel
Department of the Army
Washington, DC 20301
- 1 Dr. Robert Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 Director, Training Development
U.S. Army Administration Center
ATTN: Dr. Sherrill
Ft. Benjamin Harrison, IN 46218
- 1 Dr. Frederick Steinheiser
U. S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 Dr. Joseph Ward
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

- 1 Air Force Human Resources Lab
AFHRL/PED
Brooks AFB, TX 78235
- 1 Air University Library
AUL/LSE 76/443
Maxwell AFB, AL 36112
- 1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235
- 1 DR. T. E. COTTERMAN
AFHRL/ASR
WRIGHT PATTERSON AFB
OHIO 45433
- 1 DR. G. A. ECKSTRAND
AFHRL/AS
WRIGHT-PATTERSON AFB, OH 45433
- 1 Dr. Genevieve Haddad
Program Manager
Life Sciences Directorate
AFOSR
Bolling AFB, DC 20332
- 1 Dr. Donald E. Meyer
U.S. Air Force
ATC/XPTD
Randolph AFB, TX 78148
- 1 Dr. Ross L. Morgan (AFHRL/ASR)
Wright -Patterson AFB
Ohio 45433
- 1 Research Branch
AFMPC/DPMYP
Randolph AFB, TX 78148
- 1 Dr. Marty Rockway (AFHRL/TT)
Lowry AFB
Colorado 80230
- 1 Jack A. Thorpe, Maj., USAF
Naval War College
Providence, RI 02846

Air Force

- 1 Brian K. Waters, LCOL, USAF
Air University
Maxwell AFB
Montgomery, AL 36112

Marines

- 1 H. William Greenup
Education Advisor (EO31)
Education Center, MCDEC
Quantico, VA 22134
- 1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

CoastGuard

- 1 Mr. Richard Lanterman
PSYCHOLOGICAL RESEARCH (G-P-1/62)
U.S. COAST GUARD HQ
WASHINGTON, DC 20590

Other DoD

- 12 Defense Documentation Center
Cameron Station, Bldg. 5
Alexandria, VA 22314
Attn: TC
- 1 Dr. Craig I. Fields
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209
- 1 Dr. Dexter Fletcher
ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD.
ARLINGTON, VA 22209
- 1 Military Assistant for Training and
Personnel Technology
Office of the Under Secretary of Defense
for Research & Engineering
Room 3D129, The Pentagon
Washington, DC 20301

Civil Govt

- 1 Dr. Susan Chipman
Basic Skills Program
National Institute of Education
1200 19th Street NW
Washington, DC 20208
- 1 Mr. James M. Ferstl
Bureau of Training
U.S. Civil Service Commission
Washington, D.C. 20415
- 1 Dr. Joseph I. Lipson
Division of Science Education
Room W-638
National Science Foundation
Washington, DC 20550
- 1 Dr. John Mays
National Institute of Education
1200 19th Street NW
Washington, DC 20208
- 1 William J. McLaurin
Rm. 301, Internal Revenue Service
2221 Jefferson Davis Highway
Arlington, VA 22202
- 1 Dr. Arthur Melmed
National Institute of Education
1200 19th Street NW
Washington, DC 20208
- 1 Dr. Andrew R. Molnar
Science Education Dev.
and Research
National Science Foundation
Washington, DC 20550
- 1 Dr. Jeffrey Schiller
National Institute of Education
1200 19th St. NW
Washington, DC 20208
- 1 Dr. H. Wallace Sinaiko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

Civil Govt

- 1 Dr. Frank Withrow
U. S. Office of Education
400 6th Street SW
Washington, DC 20202
 - 1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550
- w

Non Govt

- 1 Dr. John R. Anderson
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213
- 1 Dr. John Annett
Department of Psychology
University of Warwick
Coventry CV4 7AL
ENGLAND
- 1 DR. MICHAEL ATWOOD
SCIENCE APPLICATIONS INSTITUTE
40 DENVER TECH. CENTER WEST
7935 E. PRENTICE AVENUE
ENGLEWOOD, CO 80110
- 1 1 psychological research unit
Dept. of Defense (Army Office)
Campbell Park Offices
Canberra ACT 2600, Australia
- 1 Dr. R. A. Avner
University of Illinois
Computer-Based Educational Research Lab
Urbana, IL 61801
- 1 Dr. Alan Baddeley
Medical Research Council
Applied Psychology Unit
15 Chaucer Road
Cambridge CB2 2EF
ENGLAND
- 1 Dr. Patricia Baggett
Department of Psychology
University of Denver
University Park
Denver, CO 80208
- 1 Ms. Carole A. Bagley
Minnesota Educational Computing
Consortium
2520 Broadway Drive
St. Paul, MN 55113

Non Govt

- 1 Mr Avron Barr
Department of Computer Science
Stanford University
Stanford, CA 94305
- 1 Dr. Gerald V. Barrett
Dept. of Psychology
University of Akron
Akron, OH 44325
- 1 Dr. Jackson Beatty
Department of Psychology
University of California
Los Angeles, CA 90024
- 1 Dr. John Bergan
School of Education
University of Arizona
Tucson AZ 85721
- 1 Dr. Nicholas A. Bond
Dept. of Psychology
Sacramento State College
600 Jay Street
Sacramento, CA 95819
- 1 Dr. Lyle Bourne
Department of Psychology
University of Colorado
Boulder, CO 80302
- 1 Dr. Kenneth Bowles
Institute for Information Sciences
University of California at San Diego
La Jolla, CA 92037
- 1 Dr. John S. Brown
XEROX Palo Alto Research Center
3333 Coyote Road
Palo Alto, CA 94304
- 1 Dr. Bruce Buchanan
Department of Computer Science
Stanford University
Stanford, CA 94305

Non Govt

- 1 DR. C. VICTOR BUNDERSON
WICAT INC.
UNIVERSITY PLAZA, SUITE 10
1160 SO. STATE ST.
OREM, UT 84057
- 1 Dr. Anthony Cancelli
School of Education
University of Arizona
Tuscon, AZ 85721
- 1 Dr. John B. Carroll
Psychometric Lab
Univ. of No. Carolina
Davie Hall 013A
Chapel Hill, NC 27514
- 1 Center for the Study of Reading
174 Children's Research Center
51 Gerty Drive
Champaign, IL 61820
- 1 Charles Myers Library
Livingstone House
Livingstone Road
Stratford
London E15 2LJ
ENGLAND
- 1 Dr. William Chase
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213
- 1 Dr. Micheline Chi
Learning R & D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213
- 1 Dr. William Clancey
Department of Computer Science
Stanford University
Stanford, CA 94305
- 1 Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

Non Govt

- 1 Dr. Meredith P. Crawford
American Psychological Association
1200 17th Street, N.W.
Washington, DC 20036
- 1 Dr. Fred Reif
SESAME
c/o Physics Department
University of California
Berkeley, CA 94720
- 1 Dr. Emmanuel Donchin
Department of Psychology
University of Illinois
Champaign, IL 61820
- 1 ERIC Facility-Acquisitions
4833 Rugby Avenue
Bethesda, MD 20014
- 1 Dr. A. J. Eschenbrenner
Dept. E422, Bldg. 101
McDonnell Douglas Astronautics Co.
P.O.Box 516
St. Louis, MO 63166
- 1 MAJOR I. N. EVONIC
CANADIAN FORCES PERS. APPLIED RESEARCH
1107 AVENUE ROAD
TORONTO, ONTARIO, CANADA
- 1 Mr. Wallace Feurzeig
Bolt Beranek & Newman, Inc.
50 Moulton St.
Cambridge, MA 02138
- 1 Dr. Victor Fields
Dept. of Psychology
Montgomery College
Rockville, MD 20850
- 1 Dr. Edwin A. Fleishman
Advanced Research Resources Organ.
Suite 900
4330 East West Highway
Washington, DC 20014

Non Govt

- 1 DR. JOHN D. FOLLEY JR.
APPLIED SCIENCES ASSOCIATES INC
VALENCIA, PA 16059
- 1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138
- 1 Dr. Alinda Friedman
Department of Psychology
University of Alberta
Edmonton, Alberta
CANADA T6G 2J9
- 1 Dr. R. Edward Geiselman
Department of Psychology
University of California
Los Angeles, CA 90024
- 1 DR. ROBERT GLASER
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213
- 1 DR. JAMES G. GREENO
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213
- 1 Dr. Harold Hawkins
Department of Psychology
University of Oregon
Eugene OR 97403
- 1 Dr. Barbara Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406
- 1 Dr. Frederick Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406

Non Govt

- 1 Dr. Dustin H. Heuston
Wicat, Inc.
Box 986
Orem, UT 84057
- 1 Dr. James R. Hoffman
Department of Psychology
University of Delaware
Newark, DE 19711
- 1 Dr. Lloyd Humphreys
Department of Psychology
University of Illinois
Champaign, IL 61820
- 1 Library
HumRRO/Western Division
27857 Berwick Drive
Carmel, CA 93921
- 1 Dr. Earl Hunt
Dept. of Psychology
University of Washington
Seattle, WA 98105
- 1 DR. KAY INABA
21116 VANOWEN ST
CANOGA PARK, CA 91303
- 1 Dr. Wilson A. Judd
McDonnell-Douglas
Astronautics Co. East
Lowry AFB
Denver, CO 80230
- 1 Dr. Steven W. Keele
Dept. of Psychology
University of Oregon
Eugene, OR 97403
- 1 Dr. Walter Kintsch
Department of Psychology
University of Colorado
Boulder, CO 80302
- 1 Dr. David Kieras
Department of Psychology
University of Arizona
Tuscon, AZ 85721

Non Govt

- 1 Dr. Kenneth Klivington
Alfred P. Sloan Foundation
630 Fifth Avenue
New York, NY 10020
- 1 Dr. Mazie Knerr
Litton-Mellonics
Box 1286
Springfield, VA 22151
- 1 Dr. Stephen Kosslyn
Harvard University
Department of Psychology
33 Kirkland Street
Cambridge, MA 02138
- 1 LCOL. C.R.J. LAFLEUR
PERSONNEL APPLIED RESEARCH
NATIONAL DEFENSE HQS
101 COLONEL BY DRIVE
OTTAWA, CANADA K1A 0K2
- 1 Dr. Jill Larkin
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213
- 1 Dr. Alan Lesgold
Learning R&D Center
University of Pittsburgh
Pittsburgh, PA 15260
- 1 Dr. Robert R. Mackie
Human Factors Research, Inc.
6780 Cortona Drive
Santa Barbara Research Pk.
Goleta, CA 93017
- 1 Dr. Mark Miller
Systems and Information Sciences Laborat
Central Research Laboratories
TEXAS INSTRUMENTS, INC.
Mail Station 5
Post Office Box 5936
Dallas, TX 75222

Non Govt

- 1 Dr. Richard B. Millward
Dept. of Psychology
Hunter Lab.
Brown University
Providence, RI 02912
- 1 Dr. Allen Munro
Univ. of So. California
Behavioral Technology Labs
3717 South Hope Street
Los Angeles, CA 90007
- 1 Dr. Donald A Norman
Dept. of Psychology C-009
Univ. of California, San Diego
La Jolla, CA 92093
- 1 Dr. Robert Pachella
Department of Psychology
Human Performance Center
330 Packard Road
Ann Arbor, MI 48104
- 1 Dr. Seymour A. Papert
Massachusetts Institute of Technology
Artificial Intelligence Lab
545 Technology Square
Cambridge, MA 02139
- 1 Dr. James A. Paulson
Portland State University
P.O. Box 751
Portland, OR 97207
- 1 Mr. A. J. Pesch, President
Eclectech Associates, Inc.
P. O. Box 178
N. Stonington, CT 06359
- 1 MR. LUIGI PETRULLO
2431 N. EDGEWOOD STREET
ARLINGTON, VA 22207
- 1 Dr. Martha Polson
Department of Psychology
University of Colorado
Boulder, CO 80302

Non Govt

- 1 DR. PETER POLSON
DEPT. OF PSYCHOLOGY
UNIVERSITY OF COLORADO
BOULDER, CO 80302
- 1 DR. DIANE M. RAMSEY-KLEE
R-K RESEARCH & SYSTEM DESIGN
3947 RIDGEMONT DRIVE
MALIBU, CA 90265
- 1 Dr. Peter B. Read
Social Science Research Council
605 Third Avenue
New York, NY 10016
- 1 Dr. Mark D. Reckase
Educational Psychology Dept.
University of Missouri-Columbia
12 Hill Hall
Columbia, MO 65201
- 1 Dr. Fred Reif
SESAME
c/o Physics Department
University of California
Berkely, CA 94720
- 1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007
- 1 Dr. Ernst Z. Rothkopf
Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974
- 1 Dr. David Rumelhart
Center for Human Information Processing
Univ. of California, San Diego
La Jolla, CA 92093
- 1 DR. WALTER SCHNEIDER
DEPT. OF PSYCHOLOGY
UNIVERSITY OF ILLINOIS
CHAMPAIGN, IL 61820

Non Govt

- 1 Dr. Allen Schoenfeld
Department of Mathematics
Hamilton College
Clinton, NY 13323
- 1 DR. ROBERT J. SEIDEL
INSTRUCTIONAL TECHNOLOGY GROUP
HUMRRO
300 N. WASHINGTON ST.
ALEXANDRIA, VA 22314
- 1 Dr. Robert Singer, Director
Motor Learning Research Lab
Florida State University
212 Montgomery Gym
Tallahassee, FL 32306
- 1 Dr. Robert Smith
Department of Computer Science
Rutgers University
New Brunswick, NJ 08903
- 1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305
- 1 Dr. Kathryn T. Spoehr
Department of Psychology
Brown University
Providence, RI 02912
- 1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520
- 1 DR. ALBERT STEVENS
BOLT BERANEK & NEWMAN, INC.
50 MOULTON STREET
CAMBRIDGE, MA 02138
- 1 Dr. Thomas Sticht
HumRRO
300 N. Washington Street
Alexandria, VA 22314

Non Govt

- 1 Mr. William Stobie
McDonnell-Douglas
Astronautics Co.
P. O. Box 30204
Chico, CA 95926
- 1 DR. PATRICK SUPPES
INSTITUTE FOR MATHEMATICAL STUDIES IN
THE SOCIAL SCIENCES
STANFORD UNIVERSITY
STANFORD, CA 94305
- 1 Dr. Kikumi Tatsuoka
Computer Based Education Research
Laboratory
252 Engineering Research Laboratory
University of Illinois
Urbana, IL 61801
- 1 Dr. David Thissen
Department of Psychology
University of Kansas
Lawrence, KS 66044
- 1 Dr. John Thomas
IBM Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598
- 1 DR. PERRY THORNDYKE
THE RAND CORPORATION
1700 MAIN STREET
SANTA MONICA, CA 90406
- 1 Dr. Walt W. Tornow
Control Data Corporation
Corporate Personnel Research
P.O. Box 0 - HQN060
Minneapolis, MN 55440
- 1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
3717 South Hope Street
Los Angeles, CA 90007

Non Govt

- 1 Dr. J. Uhlaner
Perceptronics, Inc.
6271 Variel Avenue
Woodland Hills, CA 91364
- 1 Dr. Benton J. Underwood
Dept. of Psychology
Northwestern University
Evanston, IL 60201
- 1 Dr. Phyllis Weaver
Graduate School of Education
Harvard University
200 Larsen Hall, Appian Way
Cambridge, MA 02138
- 1 Dr. David J. Weiss
N660 Elliott Hall
University of Minnesota
75 E. River Road
Minneapolis, MN 55455
- 1 DR. GERSHON WELTMAN
PERCEPTRONICS INC.
6271 VARIEL AVE.
WOODLAND HILLS, CA 91367
- 1 DR. SUSAN E. WHITELY
PSYCHOLOGY DEPARTMENT
UNIVERSITY OF KANSAS
LAWRENCE, KANSAS 66044
- 1 Dr. William B. Whitten, II
Department of Psychology
SUNY, Albany
1400 Washington Avenue
Albany, NY 12222
- 1 Dr. Christopher Wickens
Department of Psychology
University of Illinois
Champaign, IL 61820
- 1 Dr. J. Arthur Woodward
Department of Psychology
University of California
Los Angeles, CA 90024

Non Govt

- 1 Dr. Karl Zinn
Center for research on Learning
and Teaching
University of Michigan
Ann Arbor, MI 48104